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Ruck Deep Dive: Study #2 - Ruck Training Adaptation

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Ruck Deep Dive: Study #2 - Ruck Training Adaptation

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OBJECTIVE:

This study, the second in the MTI Ruck Deep Dive Series, was designed to assess training adaptations which correlated to rucking improvements. The initial study (Ruck Study #1) helped to identify the physical attributes which correlated with rucking performance. Combining our findings with those of previous researchers allowed us to develop the next step in our Ruck Deep Dive: **Identifying which training adaptations correlate to improvements in rucking.**

SUMMARY:

All subjects completed an initial assessment, 6-week training program and post-assessment. The assessments consisted of an Army Physical Fitness Test (2-minute push-up test, 2-minute sit-up test and 2-mile run),1RM front squat, 1RM bench press, and max rep body weight pull-ups. And, finally, a timed 10km ruck with 29kg (63.9lb).

After the initial assessment, athletes were divided into three groups based on the initial test results. Cadets trained five days per week for 6 weeks. After completing the program, cadets were reassessed following the same format as the initial test. This included an Army Physical Fitness Test, 1RM front squat, 1RM bench press, max rep body weight pull-ups and a timed 10km ruck with 29kg (63.9lb.).

KEY FINDINGS & RECOMMENDATIONS:

Recommendations for FEMALE Athletes:

- When it comes to improving rucking performance females should likely first focus on increasing lower body strength (i.e. front squat).
- Improvements in core strength and unloaded running (aerobic capacity) also have a very strong and strong, respective, relationship to female rucking improvements. These two factors should be secondary focuses for females looking to improve their rucking ability.

FIGURE 1: Coefficients of Determination for Female Athletes
Circle Size Indicates Effect Size

Recommendations for our MALE Athletes:

- Improvements in trainable factors like strength and endurance can "make-up" for deficiencies in height and weight (both of which were highly correlated to initial rucking performance).

- Surprisingly, this study found that, in general, males who increased upper body muscular endurance and core strength were likely to increase their rucking performance (assuming they start at a similar, low level like our subjects). Then, after an athlete has reach a sufficient level of strength, aerobic training should be the focus – as this will be the most beneficial determinant of rucking improvement (2,3,4,5,9).

FIGURE 2: Coefficients of Determination for Male Athletes
Circle Size Indicates Effect Size
(note the much smaller effects when compared to females)

Also, based on an athlete's current fitness level and ability, individualized training recommendations can offer more specific means of improvement. Based on our results the following recommendations are offered for individuals of high and low performance levels:

TABLE 1: Training Recommendations for Males

TRAINING RECOMMENDATION TO IMPROVE RUCK PERFORMANCE FOR A...		
	LOWER PERFORMER	HIGHER PERFORMER
Ruck Ability (10km @ 29kg)	> 90 mins	< 90 mins
	Upper Body Muscular Endurance & Core Strength	Inconclusive
Aerobic Capacity (2-mile Time)	> 14 mins	< 14 mins
	Upper Body Muscle Endurance and Strength & Core Strength	Inconclusive
Upper Body Strength (1RM Bench Press)	< 185 lbs	> 185 lbs
	Upper Body Muscular Endurance & Upper Body Strength	Lower Body Strength
Lower Body Strength (1RM Front Squat)	< 185 lbs	> 185 lbs
	Upper Body Muscular Endurance & Core Strength	Inconclusive
Total Body Strength (1RM Front Squat + 1RM Bench Press)	< 400 lbs	> 400 lbs
	Lower Body Strength and Upper Body Strength	Endurance

1. INTRODUCTION

March 18, 2015, 8 months ago, we kicked-off our "Rucking Deep Dive Study Series." Since then MTI has been neck-deep in rucking research and have completed countless pilot studies with our local lab rats.

In September MTI partnered with The University of Colorado, Colorado Springs ROTC and Springfield College, to complete our first "formal" ruck study (Ruck Study #1). This first study helped us identify the physical attributes which correlated with rucking performance. Combining our findings with those of previous researchers allowed us to develop the next step in our Ruck Deep Dive: What training adaptations best contribute to improvements in rucking?

What MTI studies have shown:

- In females, rucking performance seems highly dependent on athlete size – height and weight. A combination of size and aerobic capacity (2-mile run time) seemed to be the best predictor of rucking performance in females.

- Interesting, in females, relative upper body strength (measured by bench press 1RM divided by body weight) was almost perfectly correlated with ruck performance while relative lower body strength (measured by front squat 1RM divided by body weight) had the lowest correlation.

- In males, weight was the most highly correlated measure to male rucking performance. However, based on multi-variant measures, 2-mile times were the most predictive measure of rucking performance.

- Lastly, in males, the APFT events seemed fairly predictive of rucking performance. A combination of 2-mile time and sit-ups had a predictive strength of 82%. A combination of 2-mile time and push-ups had a predictive strength of 75%.

What other research studies have shown:

- In males, 8-weeks of weight training and 8-weeks of basic Army Standardized Physical Training (stretching, calisthenics, sprints, shuttles and distance runs) produced similar, significant improvements in very short (400m) and short (3.2km) rucking (2).

- In males, aerobic capacity and hamstring strength were the most important predictors of prolonged load bearing performance (10 miles with 18kg) (3).

- Overall, field-based training which including progressive load carriage was most effective at increasing performance. Aerobic training and resistance training alone produced much smaller effects (4).

- VO2max and improvements in peak VO2 are the best predictors of ruck performance and improvements in ruck performance over short distances (3.2km) with various loads (14, 27 and 41kg) (9).

2. METHODS

2.1 Subjects

Of the original 36 ROTC cadets who completed testing during the initial assessment, 25 complete the follow-up assessment. Table 2 contains descriptive data for the subjects.

TABLE 2: Subject Data

	Female	Male
Participants (Total)	4	21
Height (Inches)	64.50	69.86
Height SD (Inches)	+/- 1.73	+/- 2.27
Weight (Pounds)	133.75	168.09
Weight SD (Pounds)	+/- 15.97	+/- 21.19
Military Science Level (1-4)	2.50 Sophomore	2.23 Sophomore

2.2 Study Design

Initial testing took place over four days. During the first day, September cadets completed an official Army Physical Fitness Test. This included a 2-minute push-up test, 2-minute sit-up test and 2-mile run. Two days later, MTI tested the cadets on 1RM front squat, 1RM bench press, and max rep body weight pull-ups. The following day, the cadets completed a timed 10km ruck with 29kg (63.9lb.).

After the assessment, athletes were divided into three groups based on the initial test results. The three groups were separated for logistical purposes only. All cadet trained the same mix of heavy, progressed, classic barbell training, bodyweight strength training, aerobic endurance training and short intense intervals. The plan also included limited work capacity training, as well as core strength work and durability.

Cadets trained five days per week for 6 weeks. After completing the program, cadets were reassessed following the same format as the initial test. This included an Army Physical Fitness Test, 1RM front squat, 1RM bench press, max rep body weight pull-ups and a timed 10km ruck with 29kg (63.9lb.).

2.3 Statistical Analysis and Analytics

Descriptive statistics are reported as means and, at times, standard deviations. Performance changes were determined by comparing group means using standard T-Test statistics from Apple Numbers and Microsoft Excel. Finally, using IBM Watson Analytics, multiple linear regression Analysis of Variance (ANOVA) were used to test for single and multiple variable contributions to performance.

3. RESULTS

Both the male and female groups showed an average increase in all but three performance measures. Of the three measures which decreased, none were statistically significant. Also, due to the small number of female participants, some of the performance improvements, although large and possibly meaningful, did not reach the threshold for statistical significance (p = 0.05*).

A comparison between male and female improvements shows that females experienced greater improvements in upper and lower body strength. However, males improved more on their APFT event scores (push-ups, sit-ups and 2-mile run). Finally, ruck improvements for both groups were nearly identical (-7.8% and -7.9%, respectively). *Note: Negative changes on the APFT 2-mile Run and the 10km Ruck represent improvements (time to complete decreased)*

TABLE 3: Average Scores and Improvements - FEMALES

	Pre-Test	Post-Test	% Change	TTEST (p)
Participants (Total)	4	4		
Height (in)	64.5	64.5	0.0%	0.00*
Weight (in)	133.8	133.8	0.0%	0.00*
1RM Front Squat (lbs)	112.5	131.3	16.7%	0.02*
1RM Bench Press (lbs)	95.0	116.3	22.4%	0.05*
Pull-Ups (reps)	4.3	5.8	34.9%	0.01*
APFT - Push-Ups (reps)	67.8	63.3	-6.6%	0.51
APFT - Sit-Ups (reps)	87.5	85.8	-1.9%	0.76
APFT - 2-mile Run (minutes)	14.8	15.0	1.4%	0.83
10km Ruck Time (minutes)	92.4	85.2	-7.8%	0.32

TABLE 4: Average Scores and Improvements - MALES

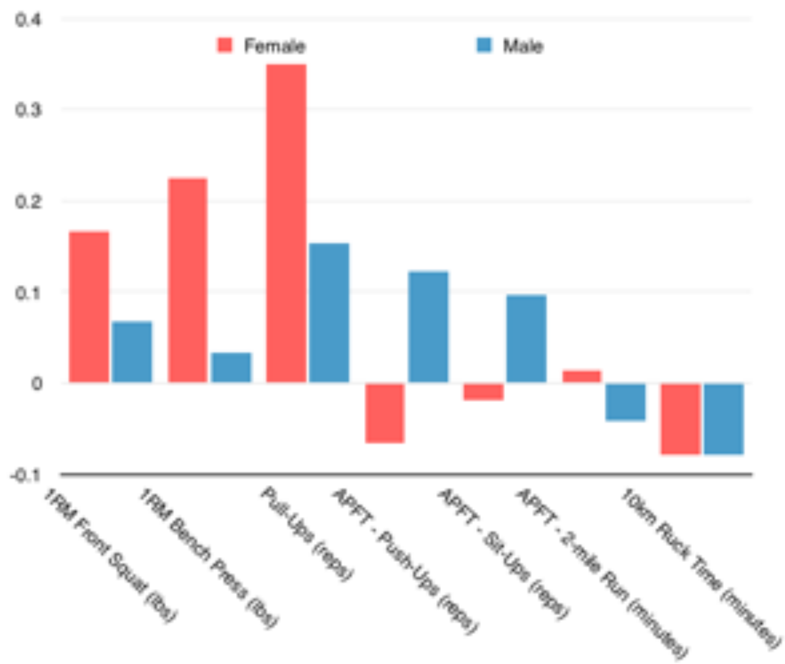
	Pre-Test	Post-Test	% Change	TTEST (p)
Participants (Total)	21	21		
Height (in)	69.9	69.9	0.0%	0.00*
Weight (in)	168.1	168.1	0.0%	0.00*
1RM Front Squat (lbs)	203.2	217	6.8%	0.00*
1RM Bench Press (lbs)	198.2	205	3.4%	0.10
Pull-Ups (reps)	13	15	15.4%	0.00*
APFT - Push-Ups (reps)	65	73	12.3%	0.00*
APFT - Sit-Ups (reps)	66.6	73	9.6%	0.01*
APFT - 2-mile Run (minutes)	14.4	13.8	-4.2%	0.00*
10km Ruck Time (minutes)	91.9	84.6	-7.9%	0.01*

After establishing the above changes the next step was to determine if these changes had a meaningful impact on rucking performance. To do this we used correlational comparisons (Pearson r) and linear regression analysis (with R squared coefficients) to investigate the relationship between the observed training adaptations and rucking performance.

TABLE 5: MALE and FEMALE Performance Changes

	Female	Male
Height (in)	0.0%	0.0%
Weight (in)	0.0%	0.0%
1RM Front Squat (lbs)	16.7%	6.8%
1RM Bench Press (lbs)	22.4%	3.4%
Pull-Ups (reps)	34.9%	15.4%
APFT - Push-Ups (reps)	-6.6%	12.3%
APFT - Sit-Ups (reps)	-1.9%	9.6%
APFT - 2-mile Run (minutes)	1.4%	-4.2%
10km Ruck Time (minutes)	-7.8%	-7.9%

GRAPH 1: Comparison of Female and Male Improvements



For our female athletes the results were fairly straight forward. Three physical adaptations seemed to be related to the subject's ruck improvements. They were Front Squat (lower body strength), 2-min Sit-Ups (core strength), and 2-mile run (aerobic endurance).

TABLE 6: FEMALE Training and Ruck Performance Relationships

	Changes in Testing Measures (Physical Abilities)	Linear Regression Relationship (R Squared)	Correlation to Rucking (r)	Strength of Relation	Statistically Significant?
Overall Female:	Front Squat (%)	0.81	-0.90	Very Strong	yes (.10)
	2-min Sit-Ups (reps)	-0.62	-0.86	Very Strong	no
	2-mile Run (time)	0.32	-0.64	Strong	no

The male results were a little more complicated. Overall, male training and performance relationships were much weaker than we saw in the females. In males, three factors showed a statistically significant relationships. However, none had more that a "moderate" interaction with ruck performance. The most powerful relationship was found between rucking performance improvement and 2-min Push-Up improvement. However, this relationship only accounted for approximately 29% of the variation in scores.

TABLE 7: MALE Training and Ruck Performance Relationships

	Changes in Testing Measures (Physical Abilities)	Linear Regression Relationship (R Squared)	Correlation to Rucking (r)	Strength of Relation	Statistically Significant?
Overall Male:	2-min Push-Up (%)	0.29	0.55	Moderate	yes (.05)
	2-min Sit-Up (%)	0.21	0.45	Moderate	yes (.05)
	Bench Press (%)	0.19	0.44	Moderate	yes (.05)

Luckily, because of the number of male participants, we were able to divide the males into "high" and "low" performer groups based on their scores during the initial assessment. This means we could examine how training related to rucking performance for a tall vs. a short athlete; a weak vs. a strong athlete; etc. Differentiating athletes this way allowed us to gain insight into how training adaptations interact with individual characteristics to produce performance changes.

Table 8 and 9 contain the R squared values for each training measure (as calculated from linear regressions between training improvements and rucking improvements). R squared is a statistical measure of how close the data fits a regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression.

TABLE 8: Break-Down of MALE Linear Regression Relationships (R Squared)

	Short	Tall	Light	Heavy	Weak Lower Body	Strong Lower Body
	<70in	>70in	<170#	>170#	FS < 185#	FS > 185#
Front Squat	0.04	0.05	0.07	0.04	0.12	0.00
Bench Press	0.02	0.49	0.45	0.40	0.39	0.05
Pull-Ups	0.01	0.11	0.02	0.25	0.28	0.01
Push-Ups	0.42	0.32	0.60	0.87	0.54	0.04
Sit-Ups	0.26	0.16	0.34	0.52	0.45	0.00
Run	0.02	0.00	0.00	0.19	0.00	0.00

TABLE 9: Break-Down of MALE Linear Regression Relationships (R Squared) (Cont.)

	Weak Upper Body	Strong Upper Body	Slow Run	Fast Run	Slow Ruck	Fast Ruck
	BP < 185#	BP > 185#	2mi > 14min	2mi < 14min	10km < 90min	10km < 90min
Front Squat	0.14	0.12	0.03	0.10	0.01	0.10
Bench Press	0.50	0.02	0.06	0.31	0.04	0.05
Pull-Ups	0.09	0.04	0.01	0.05	0.01	0.05
Push-Ups	0.6	0.00	0.00	0.44	0.06	0.50
Sit-Ups	0.44	0.00	0.03	0.28	0.02	0.37
Run	0.00	0.00	0.02	0.00	0.01	0.00

Looking at tables 8 and 9 we are able to see how an individual's initial fitness effects the relationship between training and ruck performance. In both tables, larger interactions are highlighted with bold boxes. Using the information in these tables we are able to tease out individual interactions.

For example, Athletes with weak upper bodies (1RM Bench Press < 185#) who focus their training on upper body strength and core strength will likely see more "bang for their training buck" in rucking ability. On the other hand, no single factor seems to have a significant effect on athletes with stronger upper bodies (1RM Bench Press > 185#). The factor which was most related to their improvements in rucking performance was improvements in 1RM front squat. However, this only accounted for about 12% of the variation in performance.

Note: For correlational comparisons we use the following standards to identify the "strength" of relationships.

	Pearson *r* (Correlation)
Very Strong	(-)1.00 to (-)0.80
Strong	(-)0.79 to (-)0.60
Moderate	(-)0.59 to (-)0.40
Weak	(-)0.39 to (-)0.20
Very Weak (Not Existent)	(-)0.19 to (-)0.01

4. DISCUSSION

In general, MTI, found that increases in strength and muscular endurance were highly correlated to rucking performance. These findings were quite different from previous research which placed an emphasis on aerobic capacity and peak VO2 measures (2,3,4,5,9). However, it is important to point out that most of the previous studies focused on much shorter ruck distances (3.2km) with much lighter loads (10-18kg).

The fact that our results differed so much from previous research could be a product of the heavier loads and longer distances we used. Or, more likely, the results are a product of the study population. The athletes in the study, particularly the males, began with noticeably low levels of strength (1RM Bench and 1RM Front Squat).

Previous research has established the importance of strength in military work performance (6,7,8,11,12). A study examining Canadian Special Forces (CANSOF) applicants found that soldiers with 1RM back squats over 143.6kg (315 lbs) were 5.2 time more likely to be successful in training (6). Our male athletes averaged 198 lb bench press 1RMs and 203 lb front squat 1RMs at the start of the study. These strength measures are likely well below optimal levels for rucking.

On the other hand, one estimate of male participant VO2max scores (based on 2-mile times) placed them around 45 ml/kg/min. While this is also below the 55 ml/kg/min which was found in the CANSOF study, it is proportionally higher than their strength scores. Thus, our athlete's low strength was likely preventing them from maximizing their aerobic contribution to rucking. This is one possible reason why improvements in strength, particularly upper body strength, contributed the most to rucking improvement.

Another interesting finding was that high performing athletes and/or those who excelled in at least one physical area (endurance, strength, etc.) produced "noisy" results. When looking at data from these athletes it was difficult to identify specific individual training factors because their superior abilities in one or more areas allows them to compensate for deficiencies on other areas – i.e. masking individual training effects.

In the end, the results from this study appear to hint at an underlying "base-strength requirement" for moving under load. That is to say, an athlete needs to, at the least, have a minimum level of upper and lower body strength in order to maximize their load carriage potential. Until this level is reached, improvements in strength and muscular endurance are the most important training factors. However, after reaching these levels, other factors become increasingly important to improving performances.

Unfortunately, the strength differentiations we used in this study were relatively low – as we were limited by the ability of our subjects. For our purposes "high" and "low" strength levels were divided at 185# for both front squat and bench press. It is likely that, had the study used more subjects or subjects with higher relative strength scores, we might have been able to more accurately estimate this theoretical standard.

Future research should closely examine each individual training factor in order to determine how they relate to an athlete's ability to improve ruck performance.

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